Object Oriented Programming and Design in Java

Session 20

Instructor: Bert Huang

Announcements

- Homework 4 due Monday, Apr. 19th (**next class)**

Review

- Homework tips
- Data Structures
  - Lists, Stacks, Queues
  - Sets, HashSet
  - Maps, HashMap

Today's Plan

- Applications of queues, stacks, maps, sets
- Binary search trees
- Priority Queues (Heaps)

Summary

	insert	insert at	remove	remove at	contains
lists	O(1)	O(N)	O(1)	O(N)	O(N)
stacks/ queues	O(1)	X	O(1)	X	X
set	O(1)	X	O(1)	X	O(1)
map	O(1)	~O(1)	O(1)	~O(1)	O(1)

Data Type Applications

- Abstract Data Types allow well-organized design of data applications
- Design in terms of ADTs, most environments provide efficient implementations of standard ADTs
- Know which ADTs and data structures apply in different situations

Producer Consumer Queues

- Web server receives http requests from browsers, puts request in queue
- Other threads remove from the queue, serve web pages to browsers
- Using a queue guarantees O(1) operations and first-come-first-serve scheduling

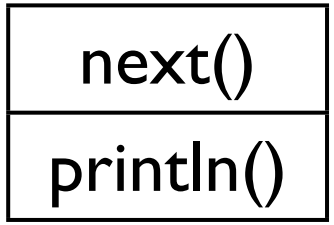
Deques

- A deque is a queue and a stack
- Insert and remove from either head or tail
  - addFirst(e), addLast(e), getFirst(), getLast()
- ArrayDeque<E> implements Queue<E>
- LinkedList<E> implements Queue<E> and Deque<E>

Stacks for Method Calls

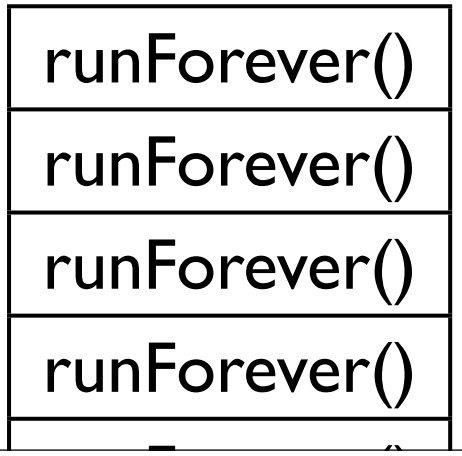
- When method is called, parameters and variables in its scope are pushed
  - Once it is evaluated, it is popped
- Nested method calls populate a stack

```
System.out.println(scanner.next())
```



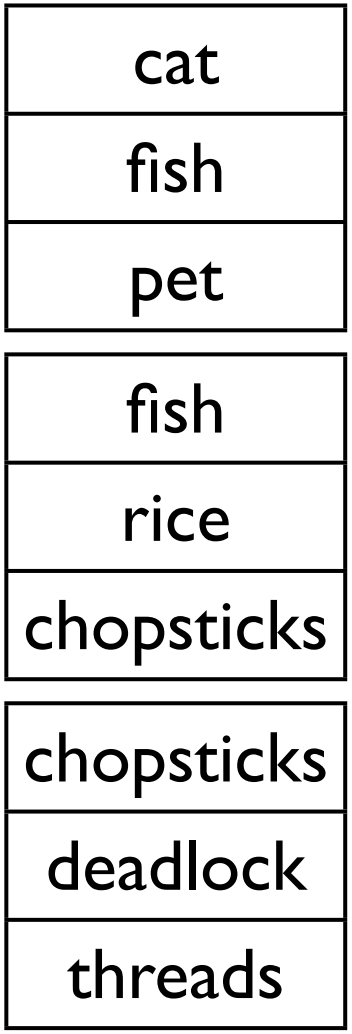
- Too many nested calls causes stack overflow, JVM out of memory

```
public void runForever() {
    runForever();
}
```



Web Search by Word Sets

- Documents can be represented as sets of keywords
- Search for keywords by calling contains() on each document
- contains() and adding new document must be fast
- search O(1) per document
- new document O(k) for k words



Word Counting with Maps

- Natural extension to storing documents as word sets: word counts
- Each word maps to an integer count HashMap<String, Integer>
- Scan through document, increment count for each word
- “to be or not to be”
- O(1) per word in document

to	be	or	not
1+1	1+1	1	1

Sorted Map ADT

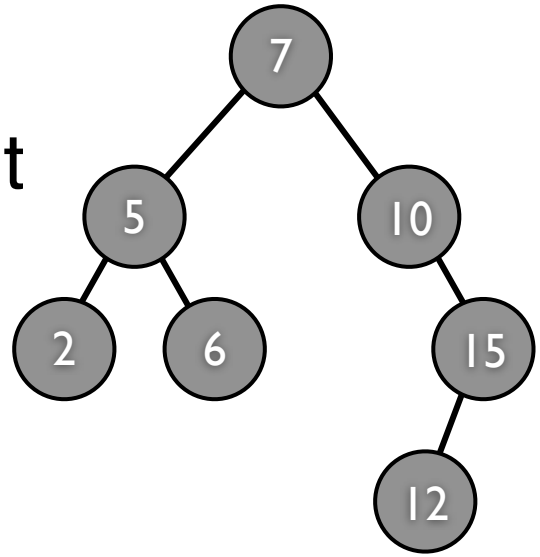
- Subtype of Map (can get value by key)
- `SortedMap<K implements Comparable,V>`
- `SortedMap<K,V> subMap(K fromKey, K toKey)`
  - firstKey, lastKey, headMap, tailMap

TreeMap

- Implements SortedMap
- put(), get(), contains() cost O(log N)
- Uses an advanced binary search tree called Red-Black Tree
  - a balanced BST
- Slower than HashMap, but keys have order

Binary Search Tree

- Tree nodes have left and right children
  - Left children are less than parent,
  - Right children are greater than parent
- At each node, O(1) comparison determines which child to move to
- Depth of tree is the worst-case time for each operation



Due Dates with BST

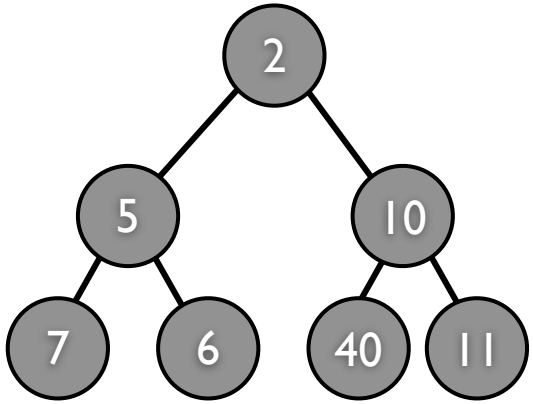
- A calendar or to-do list program may store due dates in a BST
- Allows efficient search for date ranges
  - What's due from today to Monday?
  - Show me things due after Monday

Priority Queue ADT

- Stores elements by priority (serves as the key)
  - Not really a queue, but used in similar applications
- add aka offer(E e)
- deleteMin aka poll()
- findMin aka peek()

Heaps

- Binary tree with heap order property: keys of children greater than parent's
- Running time:
  - O(log N) add,
  - O(log N) deleteMin,
  - O(1) findMin

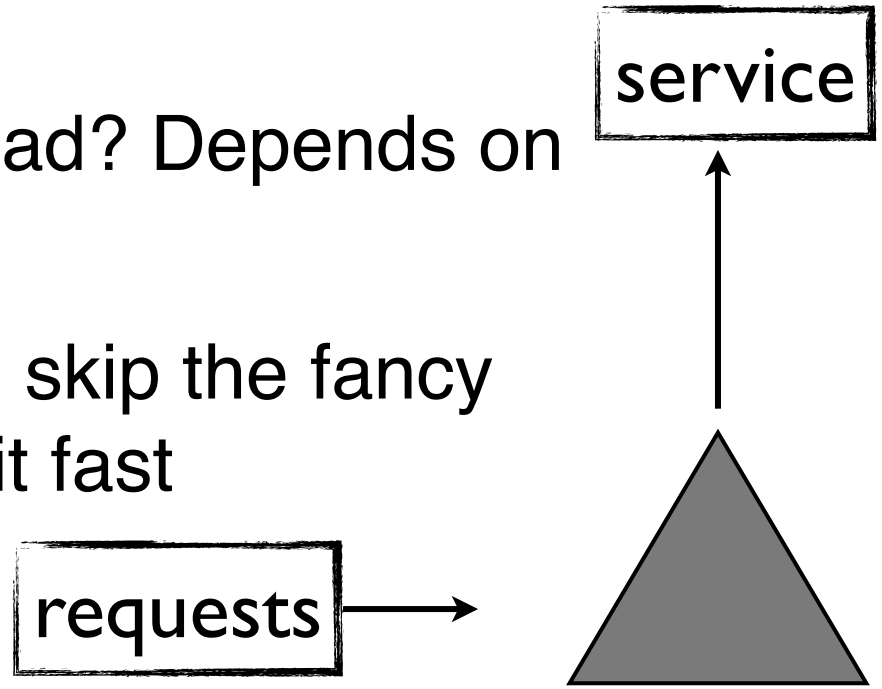


Comparison

	insert	findMin	get	get range
lists	O(1)	O(N)	O(N)	X
hashmap	O(1)	O(N)	O(1)	X
BST	O(log N)	O(log N)	O(log N)	O(N)
heap	O(log N)	O(1)	O(N)	X

Producer Consumer with Priority Queues

- Natural extension to using a simple queue, assign priority to all requests
- Consumer grabs the highest (lowest) priority element
- Is it worth the log N overhead? Depends on application
  - If consuming is very fast, skip the fancy prioritization and just do it fast



Thread Safe Data Structures

- Since data structures are designed to be extremely fast, thread safety is omitted to avoid overhead
- Java has interface ConcurrentMap, implemented by ConcurrentHashMap
- and interface BlockingQueue, implemented by ArrayBlockingQueue, LinkedBlockingQueue

Threadsafe Wrappers

- Collections has static method
  `Collection synchronizedCollection(Collection c)`
  - returns synchronized wrapper of c
- synchronizedSet, List, Map, SortedMap
- Returns *decorated* object of anonymous class
- Each unsafe method is wrapped with an object lock

Reading

- http://java.sun.com/docs/books/tutorial/collections/implementations/index.html